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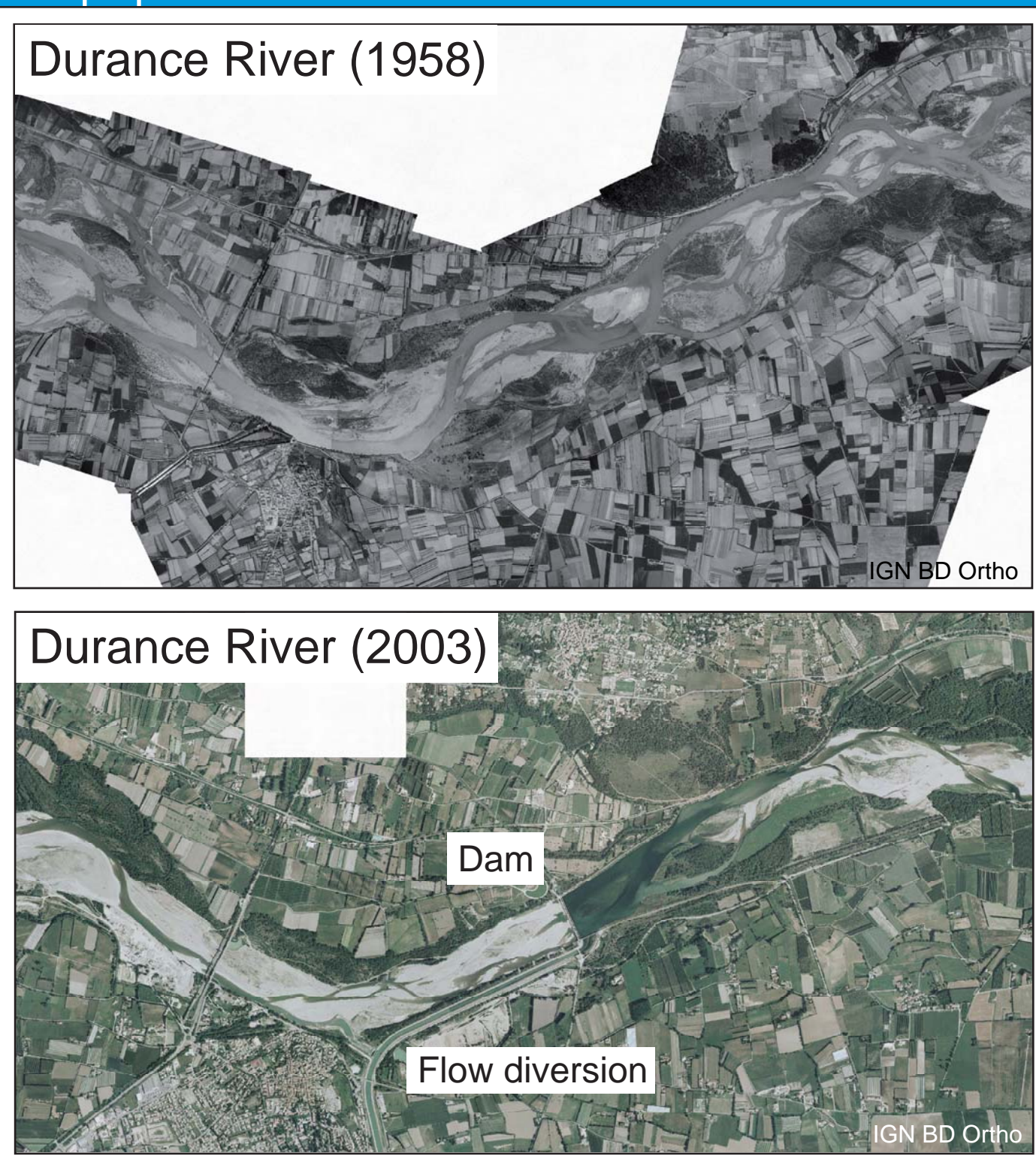


Fig.1 The Durance River: a deeply impacted gravel-bed river

GRAVEL-BED RIVERS 7

THE DURANCE RIVER: a highly modified gravel-bed hydrosystem

MULTIPLE SCALE ANALYSIS OF BED MOBILITY IN A HIGHLY MODIFIED SYSTEM (DURANCE RIVER, SOUTH-EASTERN FRANCE)

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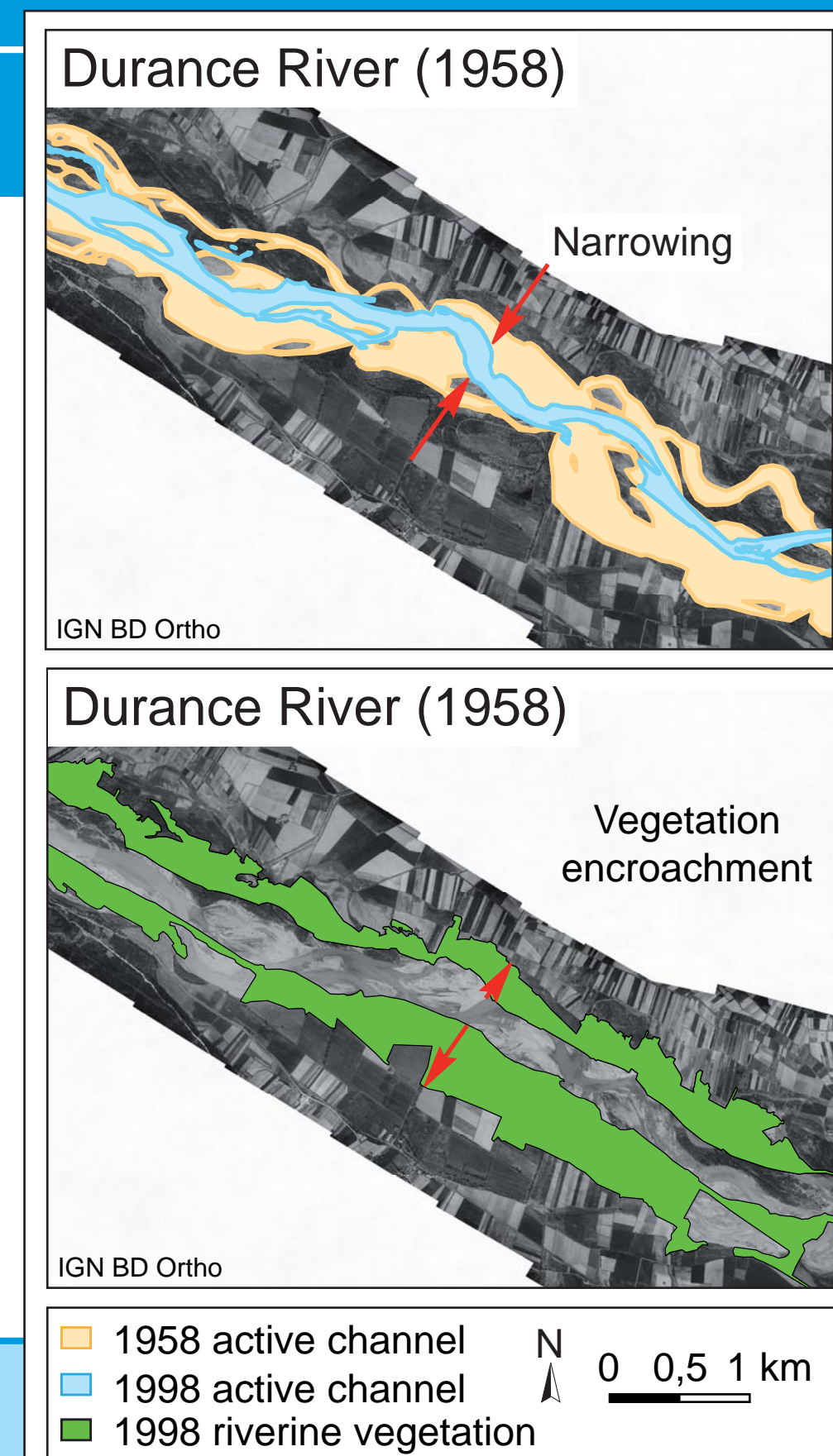


Fig.2 Narrowing of the active channel and vegetation encroachment between 1958 and 1998

1. Introduction

The Durance River is a gravel-bed river deeply impacted by gravel mining (60 million m³ during the 1960-1996 period, i.e. about one century of natural bedload transport) and flow diversion (since 1960, the lowest flow has been divided by 10 and the mean annual flow by 4, cf. fig.1). The modification of the flow regime and gravel extractions have led to a significant reduction of the active channel width (from 50 to 80% for the 1960-2000 period, cf. fig.2), a river bed degradation (maximum degradation of 5m) and, above all, a vegetation encroachment associated to an important overbank sedimentation. These changes result in a modification of flowing conditions during floods and an increase in flood risk because lateral mobility is not high enough to rework the vegetated landforms regularly.

3. Methods

We work at 3 different spatial scales, to understand and quantify sediment mobility at bedform scale, reach scale and segment scale (cf. fig.3).

Scales	Objectives	Methods
Segment	Spatial and temporal range variability of lateral mobility: identification of dynamic reaches, hydrology influence assessment and lateral mobility quantification	Diachronic study on orthophoto (1993, 1998, 2003, 2005, 2008) by active channel digitization
Reach	Bank mobility vs. bar mobility: investigation of the link between discharge, lateral bank mobility and vertical channel mobility	Event topographic survey and physical characterization of bed material (size and shape); 3D model
Bedform	Entrainment threshold variability of the particles at bedform scale: study of the entrainment threshold variability of the bar and the bank toe	PIT tags, scour chains and event topographic survey

Fig.3 Methodology of the study

2. Objectives

- Processes:** understanding and quantifying bed mobility processes and rate at different scales (segment, reach and bedform);
- Management:** understanding the role of discharge on sediment mobility in order to suggest discharge management options that would allow auto-erosion of vegetated areas in order to avoid mechanical clearcutting, currently done every 4 years.

4. Sites

We work on a 150km length segment (cf. fig.4): notably on 6 different sites, grouped on 2 areas, and located on the downstream part of the Durance river. Here we focus on one site, located at the river kilometer (RK) 205.

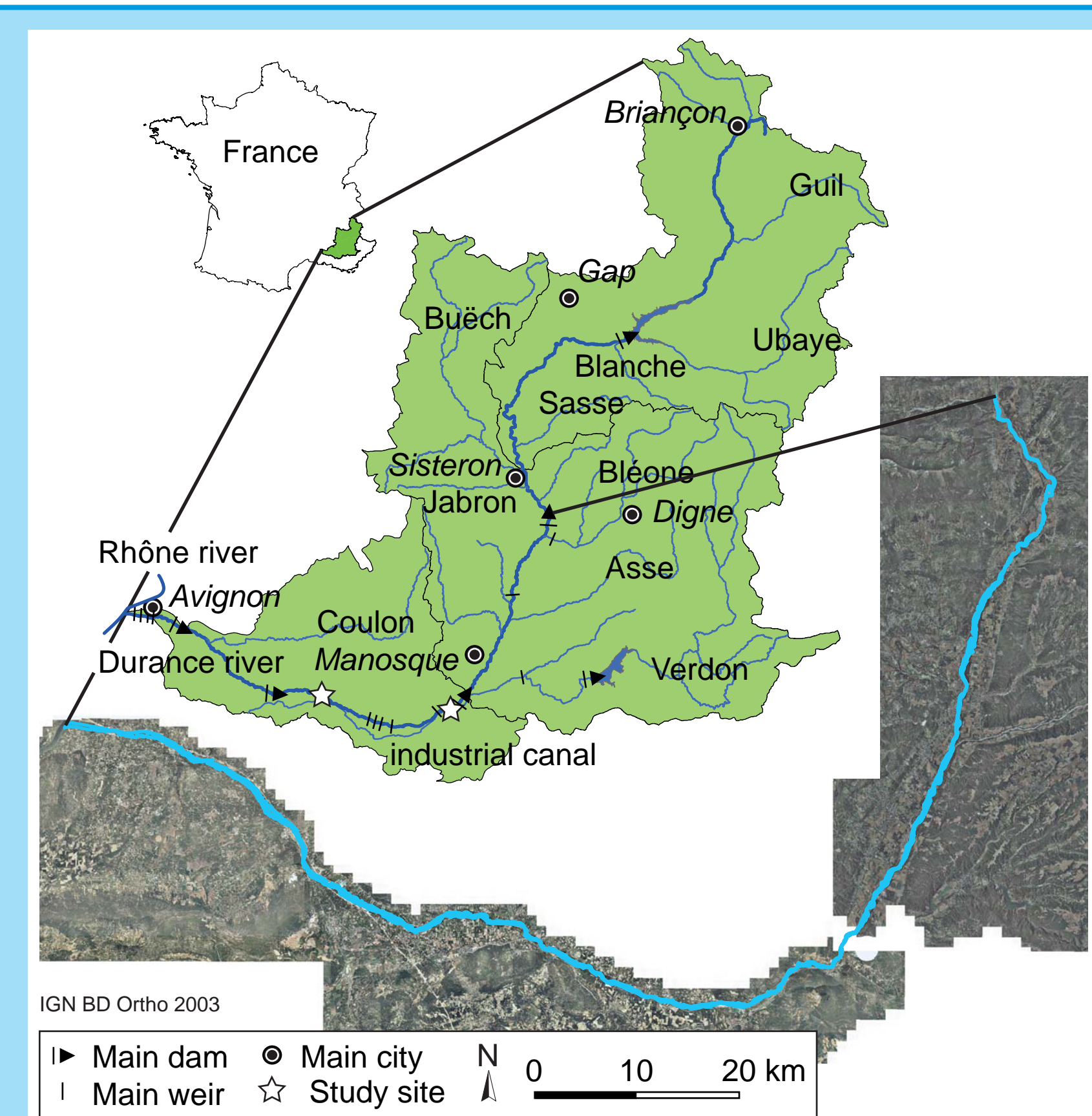


Fig.4 Sites location

5. Results

5a. At segment scale:

During the 1993-2010 period, the intensity of lateral migration (cf. fig.5 and 6) is not only function of the maximum discharge (cf. fig.7) but also probably of the occurrence of the previous flood that reworked the landforms.

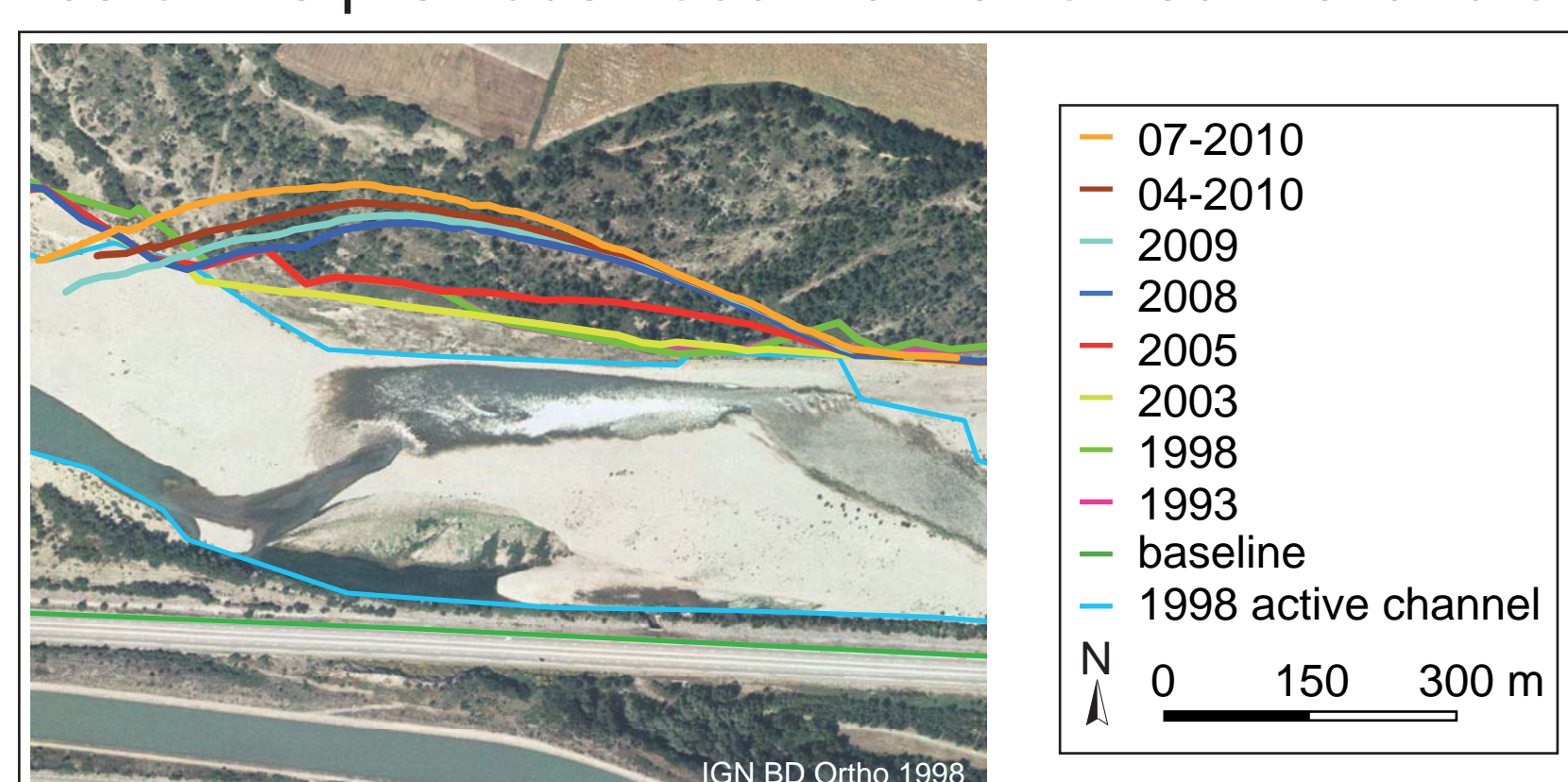
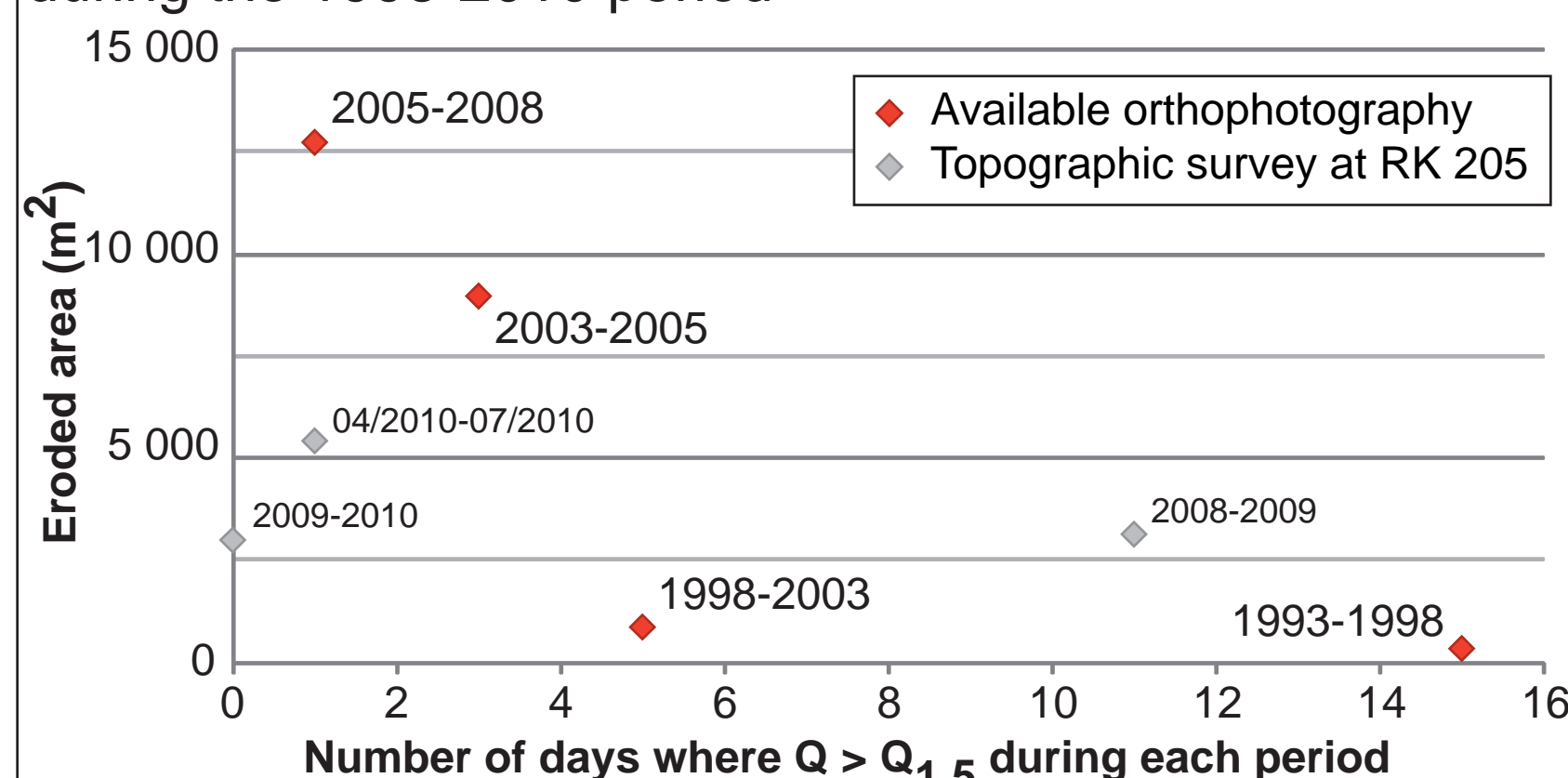


Fig.5 Quantification of lateral evolution of the bank (DSAS analysis at RK 205)

Fig.6 Lateral evolution of the bank at RK 205

Period	Eroded area (m ²)	Q _{max} (m ³ /s)	Number of days where Q > Q _{1.5}	Lateral accretion (+) or erosion (-) (m/year)	Maximum erosion (m/year)
1993-1998	307	2333	15	-0.2	4.2
1998-2003	833	1736	5	1.9	1.7
2003-2005	8941	1090	3	-5.0	14.4
2005-2008	12706	1514	1	-4.5	16.3
2008-2009	3108	964	11	-0.8	13.5
2009-2010	2965	260	0	-4.7	19.8
04/2010-07/2010	5395	1180	1	-25.2	95.3

Fig.7 Eroded area of the bank at RK 205, related to floods during the 1993-2010 period



Next steps

- Identify dynamic and potentially dynamic reaches
- Quantify lateral mobility for these reaches all along the study segment (cf. fig.3).

5b. At reach scale:

During the 2009-2010 period (cf. fig. 8 and 9), we can observe on the RK 205:

- a maximum bank erosion of 15m, corresponding to a volume of 12,880m³
- a bar accretion of about 5,660m³.

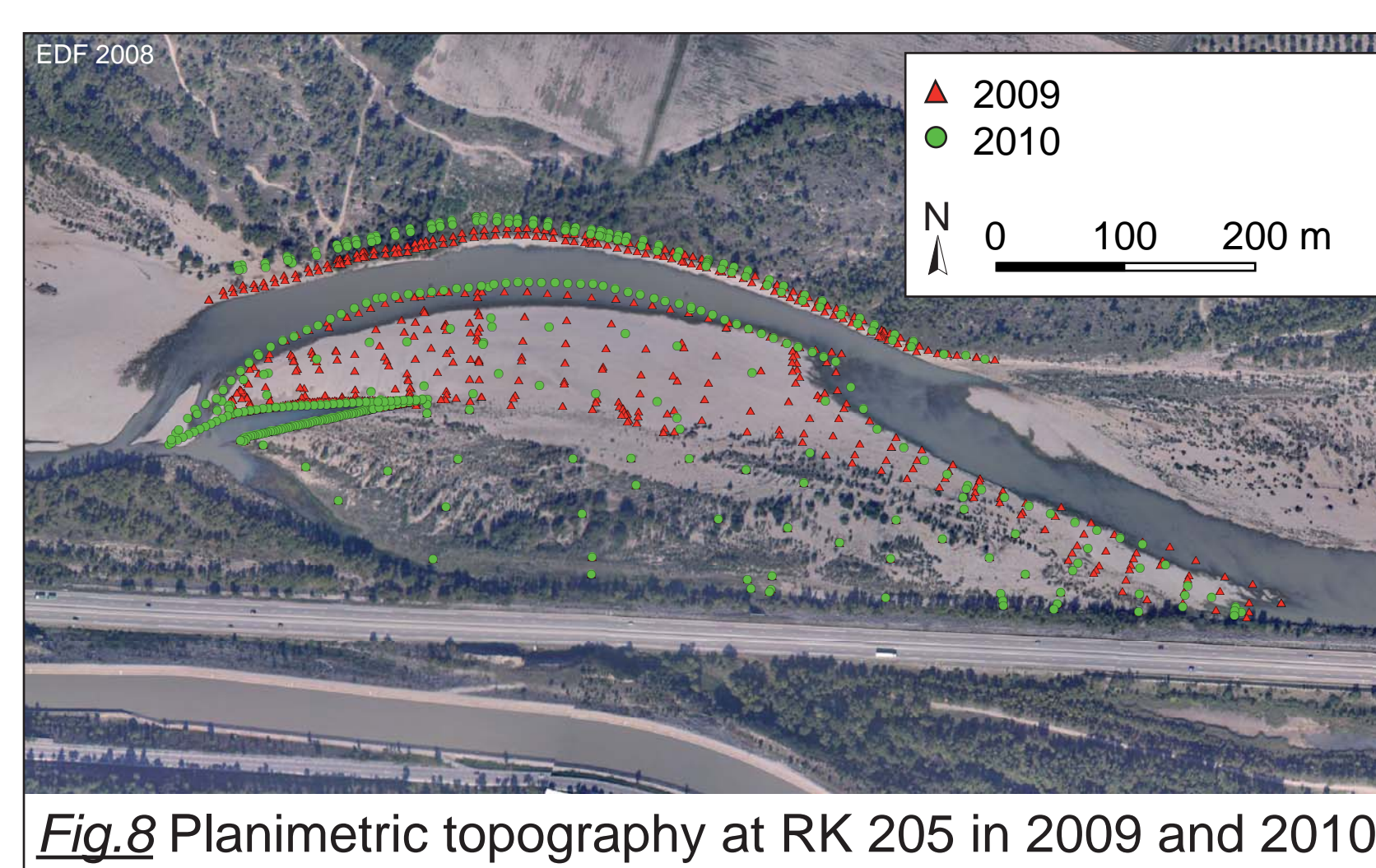
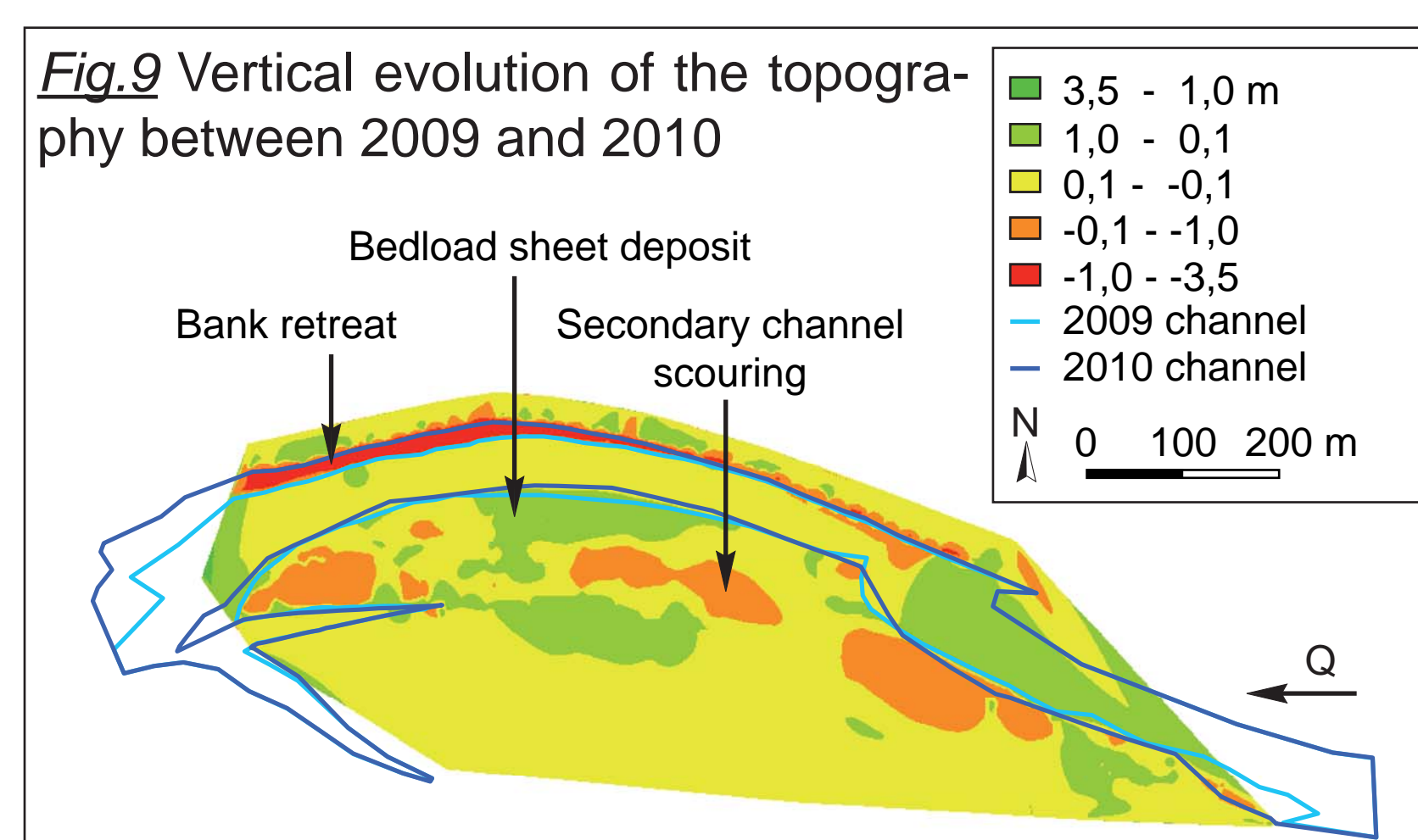


Fig.8 Planimetric topography at RK 205 in 2009 and 2010



Next steps

- Quantify the involved volumes for the others 5 study sites, and another year of survey
- Establish the link with hydrology
- Understand the involved shear stresses (hydraulic 3D model).

5c. At bedform scale:

We surveyed PIT tags (recovery rate : 41%) and scour chains (cf. fig. 10) after Q₄ flood (06/2010; 1,200m³/s) (cf. fig. 11). We observed a mean distance of transport of 90m (max 667m) with no size effect (cf. fig.12).



Fig.10 Setting up of scour chains and PIT tags at RK 205

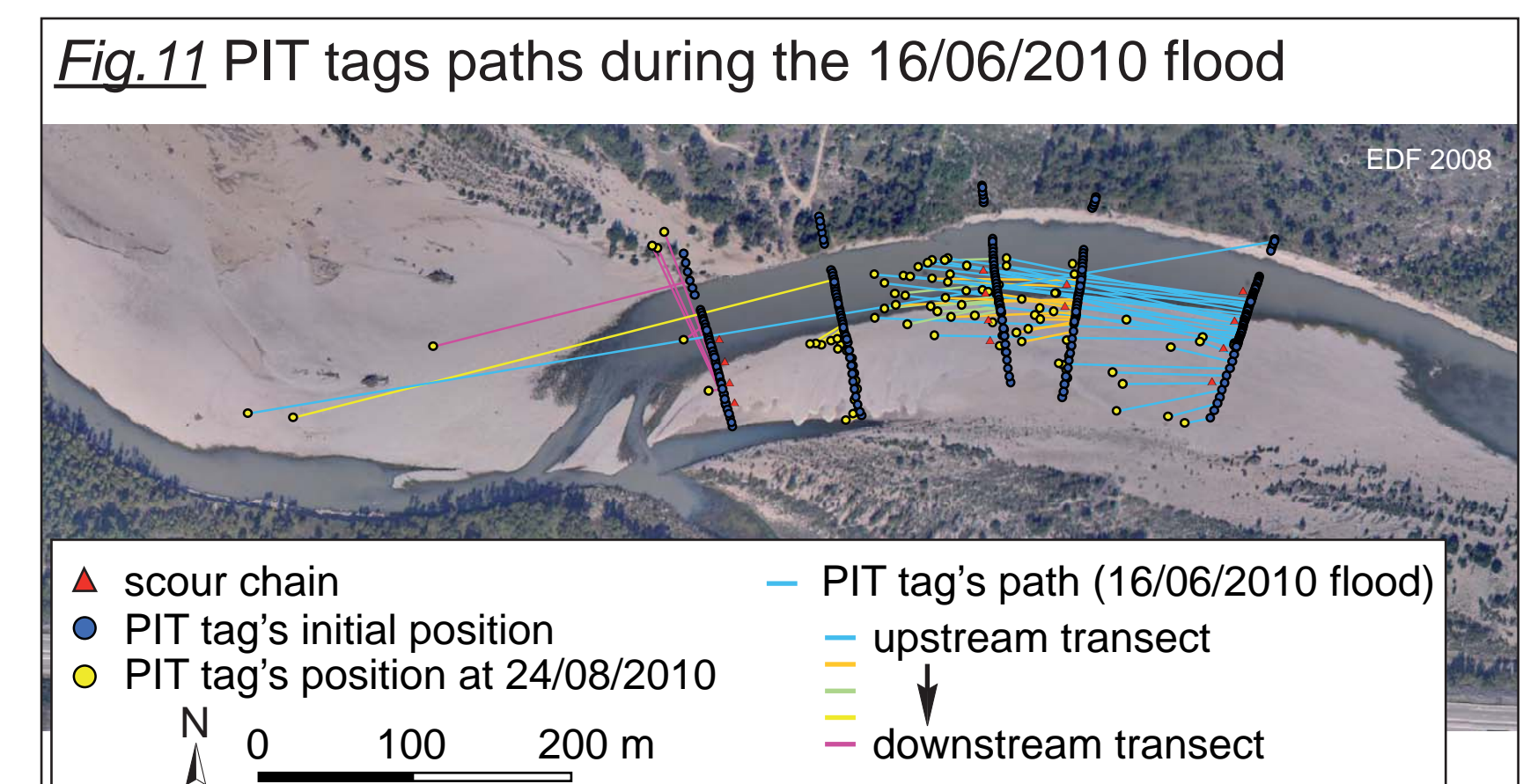


Fig.12 Comparison of proportions of mobilized and set up PIT tags for each size class

Size class (mm)	Mobilized PIT tags	Set up PIT tags	Bed-surface material
<8.0	0	0	0
11.3	0	0	1
16.0	0	0	4
22.6	0	0	7
32.0	24	23	22
45.3	25	22	18
64.0	20	23	15
90.5	18	16	16
128.0	9	11	11
181.0	3	4	4
256.0	0	1	1
512.0	0	0	0
Total	100	100	100

Next steps

- Quantify the entrainment threshold of particles
- Investigate the link between size, shape and distance of transport.

6. Perspectives

The methodology set up here allows us to quantify and begin to understand Durance bed mobility. For example, PIT tags enabled us to follow sediment particles within the bedform and from a bedform to another, but the link with magnitude and duration of floods seems to be more complex than expected.

Consequently, the next steps will be to improve the link between bed mobility, hydrology and hydraulic conditions and to cross informations obtained at each scale. Moreover, these elements will enable us to infer suggestions for the river managers.